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JPRS L/10686

26 July 1982

USSR Report

METEOROLOGY AND HYDROLOGY

No. 5, May 1982

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Translations or abstracts of all articles of the Russian-language monthly journal METEOROLOGIYA I GIDROLOGIYA published in Moscow by Gidrometeoizdat.

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UDC 551.510.522:551.582.001.57

INFLUENCE OF PROCESSES IN ATMOSPHERIC BOUNDARY LAYER ON FORMATION OF MACROSCALE CLIMATIC CHARACTERISTICS

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 (manuscript received 1 Oct 81) pp 5-18

[Article by V. P. Meleshko and B. Ye. Shneyerov, candidates of physical and mathematical sciences, A. S. Dubov and L. N. Magazenkov, Main Geophysical Observatory]

[Abstract] An effort was made to determine how sensitive the macroscale characteristics of the climatic regime computed in models are to the methods employed in parameterizing the boundary layer and which of the adopted hypotheses or values of the initial parameters are most important for a proper description of turbulent flows. By means of numerical experiments with a three-dimensional hydrodynamic model of the atmosphere a study was made of response of the computed climatic regime to methods for boundary layer parameterization in the example of two schemes: a semiempirical scheme (scheme I) and a scheme based on the hypotheses of similarity theory (scheme II). The schemes, first proposed by other authors, are examined in detail. The basic differences between the schemes are as follows: in scheme I no allowance is made for the vertical change in the direction of the wind velocity vector in the boundary layer and accordingly the change in the vector of turbulent frictional stress is not taken into account; in the first scheme no allowance is made for the differences in aerodynamic characteristics of the underlying surface on the continents and oceans; the schemes use different values of equilibrium gradients. It was found that the total quantity of heat entering the atmosphere from the underlying surface over the continents and oceans is approximately identical in both experiments, but the formation of circulation, the thermal regime and moisture cycle in the atmosphere is considerably influenced by the redistribution of this heat between explicit and latent forms. The most important conclusion drawn is that the use of similarity theory hypotheses in a model is preferable because the mean zonal distribution of temperature and the intensity of macroscale quasistationary pressure systems over the oceans and continents agree better with actual data. Figures 2, tables 4; references 23: 8 Russian, 15 Western.

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UDC 556.1

CHANGES IN GLOBAL WATER EXCHANGE

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 (manuscript received 1 Sep 81) pp 19-30

[Article by R. K. Klige, doctor of geographical sciences, Institute of Water Problems]

[Text]

Abstract: An investigation of long-term changes in individual components of the global water balance indicated that they are primarily determined by the change in observed global thermal conditions at the land surface. As a result of modern changes in climate and water exchange processes a gradual dessication of the continents and replenishment of the world ocean is occurring.

Investigations carried out during recent years indicate that as a result of a change in a number of geophysical processes and especially natural energy factors, which determined climatic fluctuations, global water exchange is experiencing considerable fluctuations. Since the end of the last century there has been an appreciable warming of climate, which attained a maximum in the 1930's-1940's, constituting almost 1°C. Then there was some dropoff of temperature to the mid-1960's, which was then replaced by its relatively small increase [4, 21, 27]. According to data published by M. I. Budyko [2], the temperature increase during the last 12 years was about 0.3°C.

An important feature is the considerably greater (approximately by a factor of 3.5) amplitude of temperature changes in the high latitudes than in the low latitudes, which is leading to a substantial change in the mean meridional temperature gradient. Computations show that an increase in air temperature in the northern hemisphere by 0.1°C will lead to a relative decrease in the meridional gradient by 0.5% for mean annual conditions [3]. There is a quite close inverse relationship between them which is changing somewhat in dependence on the magnitude of the temperature anomalies:

$$\Delta\gamma^0_{NH} = \begin{cases} -0.45\Delta t_{NH} - 0.06 \text{ with } \Delta t_{NH} < 0.1; \\ -19.44\Delta t^2_{NH} + 0.12\Delta t_{NH} - 0.62 \text{ with } 0.1 \leqslant \Delta t_{NH} \leqslant 0.3; \\ -0.86\Delta t_{NH} + 0.12 \text{ with } \Delta t_{NH} > 0.3. \end{cases}$$

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The changes in the meridional gradient in turn determine the changes in the nature of the intensity of atmospheric circulation and the corresponding changes in the regime of moisture receipt on the continents. For example, according to the data published by O. A. Drozdov [7], during the period of the warming there is a decrease in the intensity of moisture transfer and an increase in precipitation over the oceans and its decrease in the intra-continental regions. During the period 1891-1973, with a global warming by 0.5°C, there was an appreciable decrease in winter precipitation over a large part of the grain regions. During this season the decrease in the sums of precipitation in a number of cases attained 30% of the average. Although the change in mean annual precipitation was less, nevertheless in a number of regions it attained 10-15% [3].

Investigations of the correlation between the total quantity of precipitation over the area of the continents, computed both on the basis of data from direct observations [31] and on the basis of water balance computations, indicated that with a global increase in air temperature as a rule its quantity over the land increases, which can be written approximately as follows:

$$X_{con} = 798.7 + 146.8\,\Delta t_{NH} \text{ mm}.$$

At the same time, an analysis of the correlation between the total quantity of precipitation and the change in the meridional gradient revealed a tendency to an inverse dependence, which is particularly characteristic for the intracontinental regions and can be expressed approximately as follows:

$$X_{con} = 801.2 - 285.0\,\Delta\gamma_{NH} \text{ mm}.$$

The correlations between precipitation and anomalies of mean annual air temperature (Δt_{NH}) and the meridional temperature gradients ($\Delta\gamma_{NH}$) of the northern hemisphere make it possible to obtain an approximate equation for determining global precipitation over the territory of the land (without Antarctica and the islands):

$$\dot{X}_{con} = 73.39\,(10.89 + \Delta t_{NH} - 1.94\,\Delta\gamma_{NH}) \text{ mm}.$$

In general, for the territory of the land the long-term changes in precipitation anomalies (X_{con}) can also be computed with a definite degree of approximation using the water balance equation [11], taking into account changes in evaporation (Z_{con}) and river runoff (ΔY_{con})

$$\Delta X_{con} = (Z_{con} + \Delta Z_{con}) + (Y_{con} + \Delta Y_{con}) - X_{con}.$$

Water balance computations show that long-term changes in precipitation in the current century had a number of peculiarities.

For example, an increase in precipitation (somewhat more than 2%) occurred over the ocean (Fig. 1) in the late 1930's-early 1940's (during a period of warming), whereas over the territory of the continents (without Antarctica and the islands) during this period there was a sharp reduction of precipitation and the meridional gradient (about 1°C).

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The temporal variability of precipitation in Antarctica was investigated on the basis of the annual layer of snow accumulation, averaged by decades, by W. Schwerdtfeger [29], N. V. Petrov [16], and others. It was found that the rate of feeding of the Antarctic ice cover increased from the end of the 19th century to the 1930's and began to decrease by the 1940's-1950's.

The long-term variation of the change in the percentage of precipitation over the continental territory relative to ocean areas is of definite interest; it shows (Fig. 1) that with the development of a warming the percentage of precipitation over the continents begins to decrease and attains a minimum (in the limits 2%) during the period of the highest temperatures and their minimum gradients.

In general, however, for the current century against the background of a general gradual warming a small tendency to an increase in precipitation over the continents (without Antarctica) was characteristic; this amounted to about 0.25 mm (31 km^3) per year or about 0.03%. The peculiarities of the long-term variation of precipitation are very closely related to the long-term changes in mean annual air temperature and changes in its meridional gradient. With an increase in air temperature there was an increase in evaporation from the surface of the world ocean. The transport of this moisture onto the continent led to an increase in precipitation at the beginning of the warming. At the same time, with an increase in temperature there was an appreciable change in the anomalies of the meridional air temperature gradient which attained minimum values during the period of maximum warming in the 1940's. With a change in the latitudinal temperature gradient there was a change in the intensity of water vapor transport from the ocean onto the continents [2]. A decrease in the meridional temperature gradient led to a lessening of the intensity of atmospheric circulation, which finally led to a decrease in the flow of water vapor arriving in the intracontinental regions and the quantity of precipitation over a considerable part of the land decreased. The opposite situation developed in the 1950's-1960's.

Quite significant changes should occur in the current century in evaporation processes, which are determined by the relationship of heat and moisture in different regions.

The total annual evaporation as a whole from the territory of the land, without islands and Antarctica, can be determined approximately using an equation taking into account the mean annual temperature of the land ($\bar{t}_{con}$), air temperature anomalies in the northern hemisphere (Δt_{NH}), mean annual river ($\bar{Y}_{con}$) and underground runoff ($\bar{U}_{con}$) and their anomalies ($\Delta \bar{Y}_{con}$, ΔU_{con}),

[K = con; C = NH]

$$Z_к = \frac{\{11,5 + 0,03[(\bar{Y}_к + \Delta Y_к) + (\bar{U}_к + \Delta U_к)]\}(\bar{t}_к + \Delta t_{cn}) + 3,6}{1 - 0,03(\bar{t}_к + \Delta \bar{t}_{cn})}$$

and corresponding empirical coefficients.

On the basis of an analysis of the interrelationship of water-heat-energy balance equations a formula was proposed in [13] for computing evaporation through the maximum possible evaporation (Z_{evap}) and precipitation (X_{con})

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$$Z_к = Z_м\left[1 + \left(\frac{X_к}{Z_м}\right)^{-n}\right]^{-\frac{1}{n}}.$$

[K = con; M = evap]

In general, for the total territory of the continents (without Antarctica and the islands) quite satisfactory results are given by the equation

$$Z_к = Z_м\left[1 + \left(\frac{X_к}{Z_м}\right)^{-2}\right]^{-0,5} - 136,$$

[K = con; M = evap]

where evaporability can be determined using the somewhat modified L. Tyurk equation [18]

$$Z_м = 601 + 25(\bar{t}_к + \Delta t_{сп}) + 0,05\,(\bar{t}_к + \Delta t_{сп})^3$$

[K = con; M = evap]

or using the equations [1, 8, 14], taking into account the sum of temperatures above 10°C ($\sum\theta > 10$°C), for example

$$Z_{evap} = 306 + 0.2\sum\theta > 10°C.$$

An investigation of evaporability (Z_{evap}) on the continents during the period 1881-1975 shows that it, changing proportionally to variations in mean annual air temperature, could vary from 1083 mm (1884-1885) to 1141 mm/year (1938) (±2.5%) with a mean long-term value of about 1110 mm (Zubenok, 1976). Between 1881 and 1938 there was a tendency to an increase in the maximum possible evaporation on the average with a rate of about 0.7 mm/year, which then was replaced by a tendency to its decrease in the limits 0.55 mm/year (Fig. 2).

Computations of the long-term variation of total evaporation from the entire area of the continents without Antarctica (area about 125.1 million km²) made it possible to establish its variations (±6.5%) in anomalies from -39 (1805) to 22 mm/year (1938) with a mean long-term value of 526 mm (65 802 km²). In the long-term variation of total evaporation from the land it is possible to note a number of characteristic periods (Fig. 2). For example, increased evaporation was observed primarily during the years 1897-1901, 1921-1954, 1970-1975, and reduced evaporation during the periods 1881-1896, 1902-1920, 1955-1969 with a mean period of about 16 years. Evaporation was also characterized by a tendency to an increase of about 0.3 mm/year (0.07%). These changes in total evaporation from the territory of the land were determined by the nature of the relationship between the heat and water resources of the land during individual periods.

One of the important components of global water exchange is river runoff, study of whose variations shows that in general the change in runoff and total precipitation falling on the continents is quite closely related to air temperature fluctuations. Usually for large regions with an increase in temperature to a definite limit both precipitation and runoff increase. However, for individual physiographic regions the pattern can differ somewhat, especially in internal regions located in a zone of inadequate moistening [10, 15].

A decrease in the runoff of the continents in individual cases can also occur during periods of cooling when there is a decrease in evaporation from the ocean surface, a decrease in the receipts of moisture on the land, as

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Table 1

Changes in Earth's Surface Hydrosphere (Numerator -- 1908-1958 (51 Years), Denominator -- 1894-1975 (82 Years)

	Total volume, km^3	Fraction of hydrosphere, %	Volumetric change km^3/year	Total change km^3	Fraction of change %	Fraction of change of world balance component, %
Lakes	$176,4\cdot10^3$	0,01	−74 / −33	−3774 / −2706	−2,14 / −1,53	−8,62 / −9,51
Ground water	$34,2\cdot10^6$	2,47	−266 / −108	−13566 / −8856	$-3,97\cdot10^{-3}$ / $-0,26\cdot10^{-3}$	−23,79 / −31,12
Land glaciers	$40,6\cdot10^3$	$1,93\cdot10^{-3}$	−58 / −23	−2958 / −1886	−7,29 / −4,64	−5,19 / −6,63
Reservoirs	$0,8\cdot10^3$	$0,19\cdot10^{-3}$	+15 / +31	+765 / +2542	+100,00 / +100,00	+1,34 / +8,93
Land (without Arctic and Antarctica)	$34,4\cdot10^6$	2,48	−383 / −133	−19533 / −10906	−0,06 / −0,03	−35,15 / −38,33
Glaciers of Arctic islands	$83,5\cdot10^3$	$6,03\cdot10^{-3}$	−37 / −6	−1887 / −492	−2,26 / −0,53	−3,31 / −1,73
Greenland glaciers	$2,3\cdot10^6$	0,17	−275 / −37	−14025 / −3034	−0,61 / −0,13	−24,60 / −10,66
Antarctic glaciers	$21,6\cdot10^6$	1,56	−398 / −140	−20298 / −11480	−0,09 / −0,05	−35,60 / −40,35
Arctic islands and Antarctica	$24,0\cdot10^6$	1,73	−710 / −183	−36210 / −15006	−0,15 / −0,06	−63,51 / −52,74
Land as whole	$58,4\cdot10^6$	4,21	−1093 / −316	−55743 / −25912	−0,10 / −0,04	+98,66 / +91,07
World ocean	$1,34\cdot10^9$	96,54	+1093 / +316	+55743 / +25912	$+4,20\cdot10^{-3}$ / $+1,94\cdot10^{-3}$	+98,66 / +91,07
World ocean and reservoirs	$1,34\cdot10^9$	96,54	+1108 / +347	+56508 / +28454	$+4,26\cdot10^{-3}$ / $+2,13\cdot10^{-3}$	+100,00 / +100,00

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was observed in 1884-1888, 1917-1921 and 1962-1967.

In general, for the territory of the land, including regions without runoff (without the islands of Antarctica), the change in river and underground runoff was from 276 (1925) to 317 mm/year (1897, 1976), which with an amplitude of 40 mm (5004 m^3) attained fluctuations in the range ±6.5% of its mean long-term value of 300 mm, or 37 593 km^3, of which about 12 mm, or 1572 km^3, was accounted for by underground runoff.

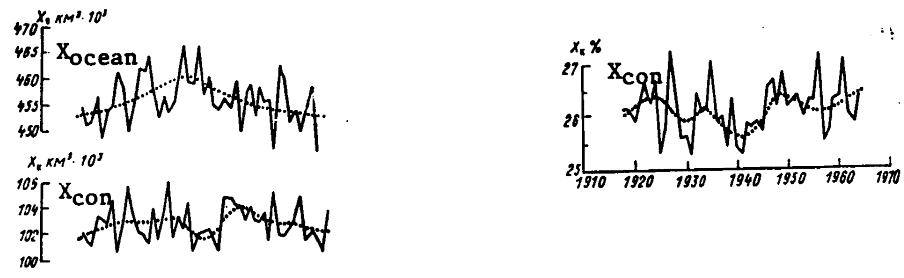

Fig. 1. Changes in quantity of precipitation over waters of world ocean (X_0), over continents (X_{con}) and percentage of continental precipitation relative to oceanic precipitation (X_{con} %).

In the course of the last hundred years the total runoff of the continents as a whole did not experience an adequately definite tendency in its changes, despite an appreciable increase in global temperatures and an increase in evaporation of about 8.8 km^3/year. The compensation of losses in runoff by evaporation occurred due to an increase in the runoff of mountain rivers as a result of the more intensive thawing of glaciers, which gave an increase in runoff volume of about 0.4 km^3/year, and also an increase in the runoff of ocean-facing slopes as a result of an increase in precipitation.

In the runoff of internal regions without runoff there is a negative tendency which leads to its decrease by about 8.8 km^3/year (Fig. 2).

A slight tendency to an increase in runoff is observed in rivers flowing directly into the ocean and a more appreciable positive tendency is characteristic for runoff from islands (Fig. 2) in a volume of about 1.2 km^3/year, caused by the tendency to an increase in precipitation in the ocean region.

The reduction in the runoff of internal regions of the land, an increase in evaporation and some reduction of precipitation led to a decrease in the total moistening of the continents, especially of regions without runoff. This circumstance was clearly reflected in a decrease in the level and volumes of lakes without runoff [9, 20].

Computations of the change in the increase in the total volume of lakes without runoff in dependence on fluctuations of their level and area show that the strongest reduction in volumes occurred in the 1940's in the period of

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greatest warming. At this time the total discharge of lake waters could attain 380 km^3/year (Fig. 3). Between 1890 and 1940 the water reserves in the lakes were reduced by almost 6000 km^3, which was about 3.4% of their total volume (176 400 km^3).

From the mid-1960's up to 1975 the total volume of the lakes had increased in the limits of about 2000 km^3, which was associated with a cooling during this period.

In general, during the period 1894-1975 the mean reduction of lake waters was about 33 km^3/year (Fig. 3, Table 1).

The present century is characterized by a decrease in the reserves of ground water on the continents [12]. Investigations show that this process transpired most intensively from the 1920's through the 1950's, when the volume of ground water decreased at a mean rate of about 860 km^3/year (Fig. 3). The changes in ground water reserves were determined primarily by thermal variations at the earth's surface. At the same time, the percentage of the anthropogenic effect with each passing year is becoming increasingly significant, especially for such regions as Europe and North America.

A major role in the change in global water exchange can be played by the earth's glacier cover by an increase or decrease in the quantity of water participating in the active cycle at the earth's surface.

The total glacier flow is about 4300 km^3/year. The overwhelming majority of this quantity is accounted for by runoff from the largest ice sheets. Each year about 2200 km^3 of water enters the ocean from Antarctica, and from Greenland -- about 800 km^3. Together this amounts to 9% of the runoff of all the rivers of the earth. In Greenland the liquid runoff constitutes almost half of its discharge, whereas in Antarctica almost the entire discharge occurs by the calving of icebergs (the total liquid runoff is 15 km^3). In the modern era icebergs in the southern hemisphere are propagated to 45-50°S and their total volume, entering into the world ocean, is equal to approximately half the annual runoff of the earth's rivers.

Investigations of many [6, 19, 22, 24, 26, 28, 30] glaciologists indicate that from the end of the 19th century an appreciable decrease of the earth's glacier cover began. Between 1900 and 1950 it decreased by approximately 10%. The average thickness of the ice in the Arctic decreased by half and its area decreased by more than 10%. The most intensive decrease in glaciation occurred in the 1930's-1940's. In the 1960's-1970's the reduction in glaciation was slowed and in many regions there was a change to an advance. This was associated primarily with a relatively small global decrease in temperature and an increase in precipitation in a number of regions.

These computations indicated that during the period from 1908 to 1958 there was a reduction in the water reserves in mountain glaciers at a rate of about 58 km^3/year, for glaciers of the arctic islands -- 37 km^3/year, for the glaciers of Greenland -- 275 km^3/year, for the glaciers of Antarctica -- 770 km^3/year. This process has now slowed considerably, although the reduction of glaciers still attains about 170 km^3/year (Fig. 3).

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An ever-increasing influence on the change in the regime of waters on the land is being exerted by the activity of man, as a result of which, on the one hand, there is an appreciable increase in the losses of water in evaporation in the process of development of irrigation and an increase in the area of reservoirs, and on the other hand, as a result of the construction of water management structures there is an accumulation of water in artificial water bodies and a replenishment of waters on the land. In general, at the present time, as a result of the creation of reservoirs, there is an annual accumulation in them of about 31 km^3 of water (Fig. 3).

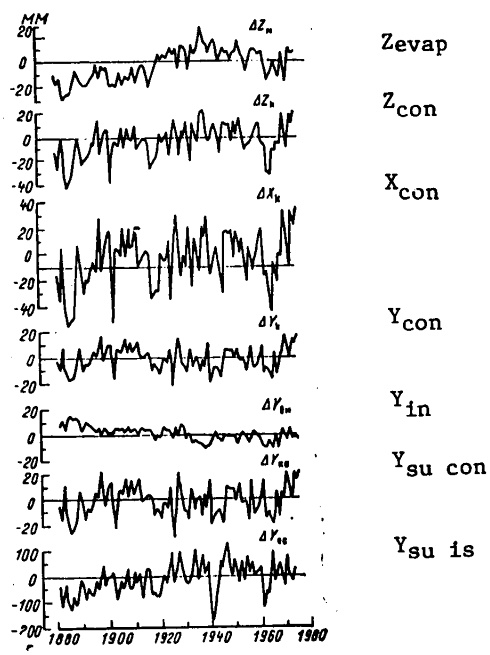

Fig. 2. Changes in region of continents of evaporability ΔZ_{evap}, evaporation ΔZ_{con}, precipitation ΔX_{con}, surface runoff as a whole ΔY_{con}, runoff of internal regions ΔY_{in}, surface and underground runoff from continents $\Delta Y_{su\ con}$ and islands $\Delta Y_{su\ is}$.

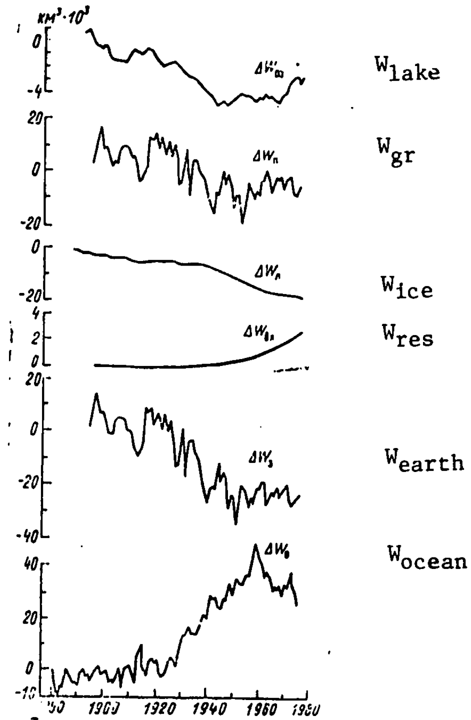

Fig. 3. Changes in reserves of water resources of lakes ΔW_{lake}, ground water ΔW_{gr}, glaciers ΔW_{ice}, reservoirs ΔW_{res}, land as whole ΔW_{earth} and world ocean ΔW_{ocean}.

Thus, as a result of the natural and artificial changes in the regime of surface and ground water of the land during the period from 1894 through 1975 there was a reduction of their mean reserves at an average rate of about 316

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Table 2

Water Balance of Land (1894-1975)

	Continents without islands and Antarctica $F_{con} = 125.1 \cdot 10^6$ km^2			Islands $F_{is} = 9.6 \cdot 10^6$ km^2			Land as a whole $F_{land} = 149 \cdot 10^6$ km^2		
	km^3	mm	% of receipts	km^3	mm	% of receipts	km^3	mm	% of receipts
Precipitation	+103262	+825	100.00	+12148	+1266	100.00	+119834	+804	100.00
Evaporation	-65802	-526	63.72	-3059	-319	25.18	-69913	-469	58.34
River runoff	-36021	-288	34.85	-8161	-850	67.18	-44182	-296	36.78
Underground runoff	-1572	-12	1.52	-928	-97	7.64	-2500	-17	2.09
Glacier runoff	---	---	---	---	---		-3555	-24	2.96
Total runoff	-37593	-300	36.40	-9089	947	74.82	-50237	-337	41.92
Balance nonclosure	-133	-1	0.12	---	---	---	-316	-2	0.26

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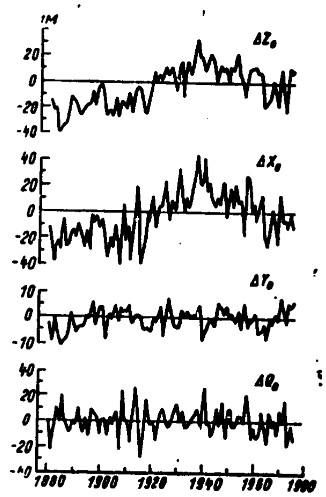
km^3/year (Table 2). This process transpired most intensively from 1918 through 1950 when the exhaustion of the water reserves of the land on the average could attain 1361 km^3/year (Fig. 3).



[subscript "0" = "ocean"]

Fig. 4. Changes in water balance components of world ocean in anomalies: evaporation ΔZ_{ocean}, precipitation ΔX_{ocean}, river and glacier runoff ΔY_{ocean} and annual increment of ocean waters ΔQ_{ocean}.

Table 3

Water Balance of World Ocean (1894-1975)

Balance elements	km^3	mm	% of discharge
Evaporation	-507153	-1404	-100.00
Precipitation	+457232	+1263	+90.15
River runoff	+44182	+122	+8.71
Underground runoff	+2500	+7	+0.49
Glacier runoff	+3555	+10	+0.70
Total runoff	+50237	+139	+9.91
Nonclosure of balance	+316	+1	+0.06

The change in the water balance of the land is very closely related to changes in the entire world water balance, including the water balance of the world ocean.

The principal discharge or loss component of the water balance of the ocean is evaporation from its surface, which in combination with the peculiarities of atmospheric circulation determines the receipts of moisture on the land.

Since the magnitude of the long-term change in evaporation from the ocean surface is closely related to the heat receipts, to a considerable degree it must be proportional to the change in thermal conditions at the earth's surface. The warming in the current century should lead to an increase in total

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evaporation from the ocean and a definite increase in the intensity of the moisture cycle. Computations [10, 17 and others] show that beginning from the end of the last century, when the evaporability anomalies could attain about -40 mm, up to the 1940's there should be a predominance of a tendency to an increase in total evaporation from the ocean (Fig. 4), which should lead to its increase by 74 mm (by almost 27 000 km^3), or by more than 5% of its mean long-term value of 507 153 km^3 (1894-1975). By the 1960's there was some decrease (about 2%).

Relatively intensive recent changes in global water exchange are causing appreciable variations in the volume of the world ocean, which during the period from 1894 through 1975 could attain from -10 194 km^3 (1916) to +9344 km^3/year (1914, 1941) (Fig. 3), on the average being about +316 km^3 (Table 3). The most substantial increment in the water mass of the ocean occurred during the period 1908-1958, when on the average it could attain about 1103 km^3/year, and if it were not for the creation of artificial water bodies, holding part of the surface waters, this quantity would have attained 1118 km^3. During the period from 1894 through 1975 the ocean was supplemented by 56 253 km^3, which is only about $4.3\cdot10^{-3}$% of its mass.

The annual quantity of precipitation on the ocean surface can be determined approximately on the basis of the change in the main components of water exchange in the world ocean: ocean volume ΔW_{ocean}, level ΔH_0, area F_{ocean}, seashore slope α, evaporation Z_{ocean}, river Y_{ocean}, underground U_{ocean} and glacier runoff A_{ocean}:

$$\Delta W_{ocean} = \Delta H_{ocean}(F_{ocean} + \alpha \Delta H_{ocean}),$$

$$X_{ocean} = Z_{ocean} - Y_{ocean} - U_{ocean} - A_{ocean} + \Delta W_{ocean}.$$

The quantity of precipitation at the ocean surface can also be determined approximately using an equation taking into account evaporation Z_{ocean}, increment of the volume of ocean waters Q_{ocean} and anomalies of mean sea surface temperature Δt_0

$$X_{ocean} = 0.98(Z_{ocean} + Q_{ocean}) - 108(1.48\Delta t_{ocean} + 1).$$

In the long-term variation of precipitation up to 1940 there was a predominance of a tendency to its increase with a mean rate of about 500 km^3/year, which then was replaced by a tendency to a decrease in precipitation of approximately the same magnitude. The lowest precipitation quantities over the ocean probably fell in 1882, 1908, 1912 and 1916 when they must have been approximately 30-40 mm below the mean long-term value, whereas the highest quantities, with an excess of the mean long-term value by an amount somewhat greater than 40 mm, corresponded to the maximum warming in the years 1938 and 1941. The total changes in precipitation during the period from 1818 through 1964 were a relatively low value of about ±3% (Fig. 4).

Thus, actual data show that with an increase in global temperature there is an increase in the total quantity of precipitation not only over the waters of the world ocean, but also in general over the territory of both the entire earth and the continents. It must be remembered that the distribution of

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precipitation over the territory of the land will change considerably: the coastal regions and the oceanic slopes should experience a considerable increase in precipitation, whereas in the intracontinental regions during periods of considerable warmings (1°C) the precipitation should be reduced.

One of the most important problems is a clarification of the possible changes in global water exchange in the future. The investigations which have been made show that these changes will be very closely related to variations in climatic conditions at the earth's surface and the development of the influence exerted by man's activity on natural processes.

An analysis of the variability of the elements of global heat exchange by means of autocorrelation functions indicated that there is a definite lag in these elements relative to climatic fluctuations. For example, the level of the world ocean has a lag relative to quite large variations in global temperature by 11 years, the ground water level -- by 12 years, the level of the Caspian Sea -- by 15 years, the level of lakes without runoff -- on the average by 6 years, etc. This circumstance makes it possible with a definite degree of reliability to foresee possible changes in individual elements of water exchange in the immediate future.

An investigation of the components of global water exchange shows that at the present time the tendencies in their changes are determined primarily by a relatively increased (by 0.5°C) air temperature at the earth's surface.

The computations show that even if the climatic conditions existing at the present time remain unchanged, at least over the course of a decade one should expect retention of existing tendencies in change in water balance components. This is associated primarily with the warming in the 20th century, as a result of which the equilibrium of water exchange changed. Thus, the level of the world ocean will also in the future continue to rise at a rate of about 1-2 mm per year, which will lead to a further replenishment of its water mass and a corresponding reduction of the water reserves on the territory of the land.

To be sure, it must be taken into account that if there are significant changes in climatic conditions, accordingly in the future fluctuations of water balance elements may occur more sharply.

There is much evidence in archeology, in the accumulation of sedimentary strata in water bodies, in peat bogs, in dendrology and in glaciology that climatic conditions in many cases were characterized by far sharper variations than have been recordered during the period of instrumental observations.

The investigations made under the direction of M. I. Budyko [5], W. Broecker [23], J. Mercer [25] and some other scientists show that as a result of the anthropogenic effect, in the future, about the year 2000, one should expect a global warming of approximately 1°C, and in the more remote future, an even greater warming. This can lead to very significant changes in the global water exchange system.

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An investigation of water balance relationships of the volumes of waters on the surface of the earth, waters of the ocean W_{ocean}, waters of the land W_{land}, with allowance for the relationship of the corresponding areas F_{earth}, F_{ocean}, F_{land} and their possible changes ΔF_{ocean}, ΔF_{land}, elements of water exchange of the ocean (precipitation X_{ocean}, evaporation Z_{ocean}, inflow of surface waters Y_{ocean}, and its changes with time ΔY_0, ocean level H_0, ΔH_0), corresponding elements of water exchange of the land X_{land}, Z_{land}, Y_{land}, as a function of anomalies of global temperature Δt, meridional temperature gradient $\Delta \gamma$ and change of all components with time T using a series of water balance equations, such as

$$W_{earth} = W_{ocean} + W_{land},\ F_{land} = F_{earth}\ (Z_{ocean} - X_{ocean}/Y_{ocean} + Y_{ocean} + Z_{ocean} - X_{ocean},$$

$$T = \frac{1}{Z_0 - X_0 - Y_0}\left\{H_0 - \frac{F_c Y_c}{\frac{\Delta F_c}{\Delta H_0}(Z_0 - X_0 - Y_0)} \times \right.$$

$$\left. \times \ln\left[1 + H_0 \frac{\frac{\Delta F_0}{\Delta H_0}(Z_0 - X_0 - Y_0)}{(X_c - Z_c - Y_c)\frac{\Delta F_c}{\Delta H_0} + F_c Y_c}\right]\right\},$$

[0 = ocean; c = land; 3 = earth]

and also the correlation equations

$$H_{ocean} = f(\Delta t),\ X_{land} = f(\Delta t, \Delta\gamma, Y_{land}),$$
$$Z_{ocean} = f(\Delta t),\ Z_{land} = f(\Delta t, X_{land}, Y_{land}),$$
$$X_{ocean} = f(Z_{ocean}, H_{ocean}, \Delta t),\ Y_{land} = f(X_{land}, Z_{land})$$

made it possible to model processes of global water exchange and carry out computations using an electronic computer. This made it possible to determine the limits of changes in the elements of global water exchange with corresponding fluctuations of thermal conditions at the earth's surface. It has therefore been established that in the case of a global cooling by 1°C in comparison with present-day conditions evaporation from the ocean will be reduced by 4% and precipitation at its surface will be reduced by 3%; the ocean level will be reduced by approximately 7 cm. On the land in this case there should also be a reduction of precipitation by 14%, a decrease in evaporation by 12% and a dropoff of river runoff by 18% with a simultaneous increase in the reserves of surface waters by approximately 167 km^3/year.

With an increase in temperature at the earth's surface, which in the opinion of many scientists is now more realistic, there will be an increase in the intensity of global heat exchange and an increase in all water balance components. For example, a temperature increase by 2.5°C should cause an increase in evaporation of the ocean by 15%, an increase in precipitation over

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it by 12%, whereas over the land precipitation, evaporation and runoff will increase on the average by 46-47% with a simultaneous decrease in water reserves by approximately 440 km^3/year, which in turn would lead to an increase in the level of the world ocean as a minimum by 180 mm.

It should be noted that the results of evaluation of possible changes in water exchange, to be sure, reflect extremely general characteristics which can be a background for more real changes in specific regions. For example, although precipitation over the land during a warming will in general increase, in the intracontinental regions it can be reduced as a result of a reduction in the intensity of circulation during warming due to the evening-out of temperatures. The results also do not take into account during a warming of the gradual reduction in the area of the snow and ice cover, which can exert a considerable influence both on evaporation processes and on heat exchange. In addition, no allowance was made for the increase in cloud cover and the quantity of water vapor in the atmosphere and this can reduce the effect of an increase in temperature and evaporation and some other factors whose influence for the time being cannot be evaluated with sufficient accuracy.

Warming can also lead to other significant changes in water exchange. For example, there can be a decay of the glacier cover in the western part of the Antarctic and this would cause a considerable replenishment of the world ocean with an intensive rise in its level with a rate up to tens of centimeters per year.

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UDC 551.509.313(-062.5)

WAVE MOVEMENTS IN LOW LATITUDES

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 (manuscript received 1 Jul 81) pp 31-41

[Article by M. R. Radzhapov, Tashkent Polytechnic Institute]

[Abstract] One of the simple methods for studying complex atmospheric processes is their representation in the form of the sum of elementary waves. However, in the low latitudes the construction of wave solutions is complicated by two factors: for the narrow equatorial zone with a width of about 500 km on each side of the equator the system of equations in hydrodynamics is essentially nonlinear and the Coriolis force at the equator becomes equal to zero. Quasigeostrophicity therefore cannot be used for macroscale movements. Accordingly, the simplification of the equations of atmospheric dynamics and the methods for their analysis by means of breakdown into elementary waves, commonly used for the middle latitudes, when applied to the low latitudes lead to extremely different results, depending on what simplifications are used in a specific model. In the low latitudes the principal types of waves are Rossby and Kelvin waves. In most studies of low-latitude wave movements the authors have neglected the second component of Coriolis acceleration ($\sin \varphi$); it is small, but at the equator it is the only term which is significant. The author here reviews this problem, examining questions related to the finding of wave solutions and their interpretation from a system of equations in hydrodynamics correct for latitudes 5-15° within the framework of a purely zonal model. The Dobryshman system of equations is used as a point of departure. The presence of variable coefficients ($\sin \varphi$, $\cos \varphi$) greatly complicates analysis of this system, which is extremely sensitive to what transformations are made with these variable coefficients. Three variants of wave solutions are outlined. The examined variants show that the results are essentially dependent on the procedure for simplifying the initial system of equations. Examples are presented which show how the dispersion expression and the solution of the equations are modified with the neglecting of small terms. It is shown that allowance for vertical velocity limits the number of wave solutions for long waves to $n = 5$. Figures 2; references 5: 3 Russian, 2 Western.

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APPROVED FOR RELEASE: 2007/02/09: CIA-RDP82-00850R000500080060-2

UDC 551.575.1+551.501.816

LIDAR SENSING OF ORIGIN AND EVOLUTION OF RADIATION FOGS

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 (manuscript received 14 Aug 81) pp 42-47

[Article by A. Ye. Tyabotov, candidate of physical and mathematical sciences, and A. P. Tikhonov, Central Aerological Observatory]

[Abstract] A study was made of the possibility of using a lidar for determining the predictors of formation and dispersal of radiation fogs and ascertaining their difference from other meteorological phenomena. The method employed is based on measurements of the scattering coefficients at two wavelengths, such as 0.53μm and 1.06μm. For small particles ($\bar{r} < 1 \mu$m) the value of the scattering coefficient σ at the wavelength λ_1 is several times greater than for λ_2. During water vapor condensation the size of the particles increases and therefore the difference in σ will decrease, evidence of a fog formation process. With the appearance of a dense haze and fog $\sigma_{\lambda_1} \approx \sigma_{\lambda_2}$. In this case the degree of polarization begins to decrease due to multiple scattering, which depolarizes the signal to a considerable degree. The method for investigating the dynamics of formation and scattering of a fog is thus based on measurement of the degree of polarization P and the ratio of the scattering coefficients $\sigma_{\lambda_2}/\sigma_{\lambda_1}$, this giving information mostly on the beginning of formation of a fog and the stage in its development. The experimental studies were made in the regions of Dolgoprudnyy, Ryl'sk and Kishinev during 1974-1978. The measurements at the mentioned wavelengths were made using a two-frequency lidar at the mentioned wavelengths. A total of 235 series of measurements were made at different seasons of the year and different times of day. These measurements were accompanied by observations of temperature, humidity and meteorological range of visibility. It was found that the lidar method is quite effective in the absence of precipitation. Specific examples are discussed. The lidar is demonstrated to be an effective tool for the meteorological service for making short-range forecasts of the appearance and dispersal of radiation fogs. Figures 2, tables 2; references: 6 Russian.

APPROVED FOR RELEASE: 2007/02/09: CIA-RDP82-00850R000500080060-2

UDC 551.577.7+551.510.72(99)

APPLICATION OF ISOTOPIC GLACIOLOGY METHOD FOR STUDYING NUCLEAR SHOT PRODUCTS IN ANTARCTICA

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 (manuscript received 10 Aug 81) pp 48-55

[Article by Ye. N. Davydov and K. P. Makhon'ko, candidate of physical and mathematical sciences, Institute of Experimental Meteorology]

[Abstract] Over a period of years the senior author carried out a layer-by-layer sampling of firn and ice samples in Antarctica in the neighborhood of Mirnyy, Molodezhnaya, Bellinsgauzen and Vostok stations. Dating of layers was by the stratigraphic method and on the basis of the content of dust particles. On this basis it was possible to analyze the composition of the snow cover in different parts of the continent. Table 1 gives the concentrations of radionuclides (Be^7, Mn^{54}, Zr^{95} + Nb^{95}, Ru^{106}, Cs^{137}, Ce^{141}, Ce^{144}) in the upper ice layer for 1969, 1970 and 1971. The observed isotopic composition is attributable to a mixture of fission fragments and activation products from nuclear shots set off in both the northern and southern hemispheres. The temporal changes in radioactive fallout and the concentration of long-lived nuclides in Antarctica has a pattern similar to that for the northern hemisphere. The lower levels of radioactive contamination and their temporal lag after 1963 are attributable to the fact that the principal source of radioactive products of nuclear shots during this period was the northern hemisphere stratosphere. During stratospheric transport most of the radioactive products were lost from the atmosphere in the northern hemisphere so that only a small part reached the southern hemisphere after a year. Water vapor is transported across the equator and reaches the Antarctic continent more rapidly than the aerosol products of nuclear explosions, the reason for this being unclear for the time being. A method is outlined for computing atmospheric fallout and atmospheric concentration of these products in preceding years when direct measurements were not made. Also discussed is the transformation of the properties of an aerosol during its transport from the northern hemisphere to the shores of Antarctica. The time required for the movement of air masses from the northern hemisphere into the southern hemisphere in the troposphere and stratosphere was ascertained, as was the time of half-elimination from the stratosphere in the south polar region. Figures 3, tables 4; references 17: 10 Russian, 7 Western.

APPROVED FOR RELEASE: 2007/02/09: CIA-RDP82-00850R000500080060-2

UDC 546.49:631.4(470.311)

EXPERIMENTAL EVALUATION OF SOME PARAMETERS OF MERCURY MIGRATION IN SOIL SURFACE LAYER

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 (manuscript received 14 Jul 81) pp 56-63

[Article by B. K. Blinov, Institute of Experimental Meteorology]

[Abstract] A field experiment was carried out for ascertaining the characteristics of migration of mercury from the soil surface layer. The work was done in two water-balance areas each measuring 100 m^2. In the spring of 1976 mercury sulfate was applied on the snow cover of one of these areas, whereas the other area served as a control. The analysis of samples was made by the atomic-absorption method using a MAS-50 spectrophotometer and the mean standard error in the determination did not exceed 10%. Mercury profiles in the soil of the experimental sector were determined 0.5, 1.5, 2.5 and 3.5 years after onset of the experiment. It was determined that the principal role in the transport of Hg from the surface layer is played by evaporation. During the warm season of the year about 60% of the mercury present in the surface layer passes into the air. The rate of evaporation for Moscow Oblast is characterized by an evaporation coefficient equal to 1.52 ± 0.42 $year^{-1}$. The next most important process is transport of Hg into the depth of the soil; as a result of Hg transport into the underlying layers from the horizon 0-10 cm about 14% of the annual surface receipts of Hg disappears into the depth of the soil. Runoff carries away about 5% of the surface receipts; the runoff coefficient is $1.5 \cdot 10^{-4} \pm 0.32 \cdot 10^{-4}$ mm^{-1}. No more than 0.5% passes into plants and is removed with the harvest; this is described by the biological absorption coefficient, which for grain crops is equal to 0.5 ± 0.2. The data presented here can be used in predicting the contamination of soddy-podzolic soils for a period up to several years. Figures 1, tables 3; references 25: 24 Russian, 1 Western.

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APPROVED FOR RELEASE: 2007/02/09: CIA-RDP82-00850R000500080060-2

UDC 551.465.535(267.6)

DYNAMIC-STOCHASTIC COMPUTATIONS OF SEASONAL GEOSTROPHIC CIRCULATION OF SURFACE WATERS IN EASTERN TROPICAL ZONE OF INDIAN OCEAN

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 (manuscript received 14 Jul 81) pp 64-70

[Article by V. A. Sokolov, candidate of physical and mathematical sciences, and V. B. Kholmanov, State Oceanographic Institute]

[Text]

Abstract: The authors describe methods for a diagnostic computation of currents and three-dimensional smoothing of density fields by means of which it was possible to determine the circulation of waters. The initial data are the density field of sea water, bottom relief and dispersion of these values, averaged over the area of 1° squares. The results of the computations are presented in the form of vector maps of summer and winter circulation of surface waters of the ocean giving evaluations of the accuracy in determining these vectors. A comparative analysis of the constructed pattern of currents and the results of investigations made earlier is presented.

Computations of the circulation of waters were made by the method in [7, 8], which makes it possible to determine the three components of the geostrophic velocity vector on the basis of the stipulated density field of sea water and bottom relief, taking into account information on the error in stipulating these initial data. The results of the computations are represented in the form of evaluations of the mathematical expectations and dispersions of current velocities, stable relative to the errors in stipulating the initial data.

A stability of the results is achieved because the current velocities at each investigated horizon are determined from solution of an overdetermined system of equations whose realization is accomplished taking into account the dispersions of the density field, bottom relief and the current velocity values at the reference horizon. The indicated system consists of the continuity

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equation, integrated vertically from the surface to the bottom

$$\left(\frac{\beta}{f}H-\frac{\partial H}{\partial y}\right)v-\frac{\partial H}{\partial x}u=\frac{g\beta}{f^2}\int_0^H\frac{\partial\rho}{\partial x}z\,dz-\frac{g}{f}\left[\left(\frac{\beta}{f}H-\frac{\partial H}{\partial y}\right)\int_z^H\frac{\partial\rho}{\partial x}dz+\frac{\partial H}{\partial x}\int_0^H\frac{\partial\rho}{\partial y}dz\right] \quad (1)$$

and two equations carrying information on the zero approximation of the sought-for current velocities, read from some horizon z = G at which the approximate current values u(G) and v(G) are considered a priori known:

$$v-u=-\frac{g}{f}\left(\int_z^G\frac{\partial\rho}{\partial x}dz+\int_z^G\frac{\partial\rho}{\partial y}dz\right)+v(G)-u(G), \quad (2)$$

$$v+u=-\frac{g}{f}\left(\int_z^G\frac{\partial\rho}{\partial x}dz-\int_z^G\frac{\partial\rho}{\partial y}dz\right)+v(G)+u(G). \quad (3)$$

The coordinate system was situated at the undisturbed ocean surface; the x-, y-, z-axes are oriented in the directions to the east, north and downward respectively. All the remaining notations are those generally employed.

In this case G = H and the velocities u(G) and v(G) were assumed equal to zero with an accuracy ±3 cm/sec.

The solution of system (1)-(3) was determined using the generalized least squares method (GLSM) [2], which in comparison with the least squares method (LSM) [1] has the advantage that its realization is unrelated to the assumption of a normal law of distribution of errors in stipulation of the right-hand sides of the considered system of equations. The solution has the form

$$\vec{V}=(A'WA)^{-1}A'W\vec{F}, \quad (4)$$

$$R(\vec{V})=(\vec{F}-A\vec{V})'W(\vec{F}-A\vec{V}), \quad (5)$$

where $\vec{V}\equiv\{u, v\}$ is the vector of evaluations of the sought-for values of the horizontal currents; R(V) is the covariation matrix of the V vector, A is the matrix of system of equations (1)-(3); $\vec{F}$ is the vector of the right-hand sides of equations (1)-(3); W is a weighting matrix, determined in the form $W = N^{-1}$, where N is the covariation matrix of the $\vec{F}$ vector. The methods for stipulating the covariation matrix N, which is a function of the second statistical moments of the density field, bottom relief and current velocities at the reference horizon, were described in detail in [8].

Computations of the circulation of waters were made using the mean long-term data on the field of density ρ of sea water during the period of the summer and winter seasons (northern hemisphere). We used 9079 hydrological stations

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at which observations were made from 1960 through 1977. The density fields were stipulated at 24 standard horizons in the interval from 0 to 4000 m. At each horizon the sea water density values, averaged over the area of 1° squares, were smoothed. The smoothing was carried out in one of four variants:

$$\tilde{\rho}_{ij} = c_1 \cdot 0{,}05\,(\rho_{i-1,\,j-1} + \rho_{i+1,\,j-1} + \rho_{i+1,\,j+1} + \rho_{i-1,\,j+1}) + \tag{6}$$

$$+ c_2 \cdot 0{,}13\,(\rho_{i-1,\,j} + \rho_{i+1,\,j} + \rho_{i,\,j-1} + \rho_{i,\,j+1}) + c_3 \cdot 0{,}28\,\rho_{i,\,j},$$

$$\tilde{\rho}_{i,\,j} = c_4 \cdot 0{,}13\,(\rho_{i-1,\,j} + \rho_{i+1,\,j} + \rho_{i,\,j-1} + \rho_{i,\,j+1}) + c_5 \cdot 0{,}48\,\rho_{i,\,j}, \tag{7}$$

$$\tilde{\rho}_{i,\,j} = c_6 \cdot 0{,}25\,(\rho_{i-1,\,j} + \rho_{i+1,\,j}) + c_7 \cdot 0{,}5\,\rho_{i,\,j}, \tag{8}$$

$$\tilde{\rho}_{i,\,j} = c_6 \cdot 0{,}25\,(\rho_{i,\,j-1} + \rho_{i,\,j+1}) + c_7 \cdot 0{,}5\,\rho_{i,\,j}, \tag{9}$$

where the subscripts i and j indicate the sequence number of the point in the zonal and meridional directions and c_1–c_7 are weighting factors dependent on the depth of the horizon and on the thickness of the layer of the main thermocline.

The choice of the smoothing variant was determined in dependence on the position of the point for determining density (i, j) relative to the contour of the lateral boundaries at this horizon.

In those cases when not one of the enumerated smoothing variants could be realized the density value at the point (i, j) remained unchanged.

The latter circumstance was taken into account when determining the horizontal derivatives of the density field, which were determined in the following way:

a) determined from the area of a 1° square if not one of the four points situated at its corners touched the bottom;
b) were assumed equal to zero if at least one of the points touched the bottom or was situated within its limits.

We note that the smoothing formulas (1)-(4) with the values

$$c = 1,\ c_2 = 1,\ c_3 = 1,\ c_4 = 1,\ c_5 = 1,\ c_6 = 1,\ c_7 = 1$$

correspond to the formulas which are cited in [4].

When carrying out smoothing of the density fields in the investigated region of the Indian Ocean we took the following peculiarities of the used observational data into account:

1) Most of the data were in the limits of the baroclinic layer.
2) Within the limits of the lower boundary of the baroclinic layer the accuracy in measuring anomalies of the hydrological fields is commensurable with the amplitude of these anomalies.

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3) with an increase in latitude there is an increase in the thickness of the baroclinic layer.

Taking into account the factors enumerated above, we introduce the dependence of the weighting factors in formulas (6)-(9) on the depth of the lower boundary of the baroclinic layer and on the depth of the horizon at which smoothing is carried out. In determining these coefficients at the ocean surface smoothing was accomplished using the formulas proposed in [4] since they are most effective under conditions when the amplitude of changes in the density field exceeds the observation errors. Beyond the limits of the baroclinic layer the amplitude of the changes in sea water density anomalies is commensurable with or less than the accuracy of its determination. Accordingly, it is desirable that the filtering of these fields be carried out by means of moving averaging over the area.

In the interval between the upper and lower boundaries of the thermocline the weighting factors were determined from the conditions of linear conversion from the smoothing formulas to averaging. This makes it possible for the coefficients c_1-c_7 to propose the formulas

$$c_1 = \frac{11}{9D} z_1 + 1, \quad c_2 = \frac{-0,17}{1,17D} z_1 + 1, \quad c_3 = \frac{-1,52}{2,52D} z_1 + 1,$$

$$c_4 = \frac{7}{13D} z_1 + 1, \quad c_5 = \frac{-7}{13D} z_1 + 1, \quad c_6 = \frac{1}{3D} z_1 + 1,$$

$$c_7 = -\frac{1}{3D} z_1 + 1,$$

where D is the depth of the lower boundary of the baroclinic layer and z_1 is determined from the expressions

$$z_1 = \begin{cases} z \text{ with } z \leqslant D, \\ D \text{ with } z > D. \end{cases}$$

When carrying out computations the D values changed linearly from 500 m at a latitude of 1° to 1500 m at latitude 20°.

In the process of smoothing of density at the horizons situated near the bottom there can be situations when the density at some nodal points may remain unchanged. Taking this circumstance into account, the values of the parameters

$$\int_z^H \frac{\partial \rho}{\partial l}\, dz, \quad \int_0^H \frac{\partial \rho}{\partial l} z\, dz,$$

(here l = x, y) are assumed to be approximately equal to

$$\int_z^{H_m} \frac{\partial \rho}{\partial l}\, dz, \quad \int_z^{H_m} \frac{\partial \rho}{\partial l} z\, dz,$$

where H_m is the minimum depth of the ocean within the limits of the investigated square.

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When carrying out computations the error in stipulating the smoothed values of the density field was evaluated at 10^{-5} g/cm^3, $\sigma(u(H))$, $\sigma(v(H))$ = 3 cm/sec, whereas the accuracy in stipulating bottom relief, which was determined from the atlas [3], was assumed equal to 10 m.

It should be noted that in this method the computed values of the dispersions of currents (diagonal elements of the covariation matrix R(V)) characterize the consistency of equation (1) with the a priori information on current velocities at the reference horizon, represented in equations (2) and (3). Information on the errors in stipulating the initial data is used in determining the statistical weights of equations (1)-(3). For example, the increase in the errors in stipulating bottom relief and to a somewhat lesser degree the density field of sea water leads to a decrease in the statistical weight of equation (1), whereas an increase in the $\sigma(u(H))$, $\sigma(v(H))$ values reduces the statistical weights of equations (2) and (3). If the computed values $\sigma(u)$ and $\sigma(v)$ constitute not more than 20%, this means that within the limits of accuracy of the geostrophic model of the circulation of waters, with allowance for the error in stipulating the initial data, equation (1) and the a priori information, written in the form of equations (2)-(3), do not contradict one another.

The following parameter was introduced for characterizing the accuracy of the computed values of the current vectors

$$\gamma = \sqrt{\frac{\sigma(u)^2 + \sigma(v)^2}{u^2 + v^2}}\,100\%,$$

representing an evaluation of the relative error in determining the modulus of the velocity vector. The computations of currents made for 1° squares are represented in the figure in the form of maps of summer and winter (northern hemisphere) circulations of waters at the surface of the investigated part of the Indian Ocean.

On these maps the information on the accuracy of the computed fields of water circulation was plotted in the following way. The results were divided into three groups with respect to the γ coefficient. The first included the vectors with $\gamma \in [0, 30\%]$, the second -- with $\gamma \in [30, 60\%]$, and the third -- with $\gamma > 60\%$. The notation of the vectors belonging to the first and second groups is given in explanations to the figure. The vectors belonging to the third group have not been plotted on the map, as a result of which gaps were formed in several places on them.

An analysis of the results indicated that the first group included 43%, the second group 44% and the third group 23% of the computed values of the current vectors. It follows from this fact that in determining currents at the surface in the overwhelming majority of cases the assumption of the absence of velocities in the bottom layer fully agrees with the geostrophic model of circulation of waters represented in the form of equation (5).

Computations of the γ evaluation and the introduction of three gradations of the current vectors relative to this parameter made possible a graphic discrimination on the maps of those regions with a small, moderate and also

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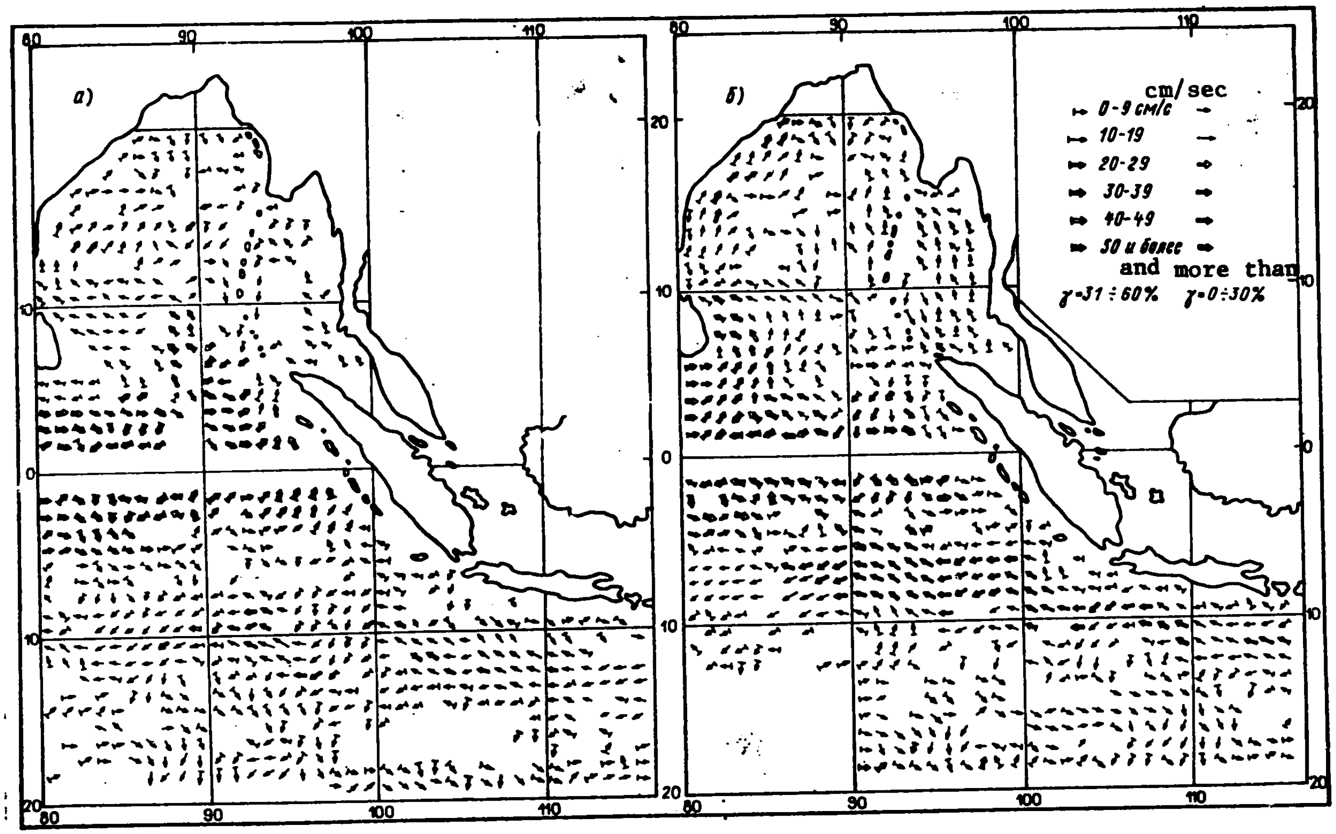

Fig. 1. Geostrophic currents at the surface during the seasons of the northeast (winter) (a) and southwest (b) (summer) monsoons.

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considerable level of error in the results, which substantially simplifies carrying out the analysis of the constructed pattern of water circulation. In the overwhelming majority of cases the current vectors belonging to the second and third groups were situated in zones of weak horizontal flows, in the shelf zone or in the equatorial zone, that is, precisely where disruption of the geostrophic balance was entirely regular. With respect to cases of the appearance of vectors of the second and third groups in regions with powerful clearly expressed flows, such as the Southern Trades Current (STC), this fact, in all probability, was caused by the poor consistency of the density field and bottom relief.

Now we will proceed to a geostrophic analysis of the resulting maps of currents. According to existing concepts [5], in the northern hemisphere the most significant element in the circulation of waters is the monsoonal current, but to this time it has not been possible to discriminate a unified flow of this current in geostrophic circulation computations [9]. Now this current is expressed quite clearly in the results (see Fig. 1). From winter to summer it changes the direction of its movement, reversing itself; it intensifies considerably (from 10-15 cm/sec in winter to 25-30 cm/sec in summer), and bending around Sri Lanka from the southeast, gives rise to the East Hindustan Current. The latter, as indicated by computations, also changes considerably from season to season (from 5-15 cm/sec in winter to 18-25 cm/sec in summer), which in turn leads to an intensification of the anticyclonic circulation of waters in the Bay of Bengal. Such a sequence in relationships in the circulation system and a numerical evaluation of the variability of the transport of waters were not given earlier in the literature.

During winter it is possible to trace the surface equatorial countercurrent, whose powerful flow penetrates from west to east to the shores of Sumatra between 2 and 4°N, having velocities from 20 to 50 cm/sec. It should be noted that in computations made earlier [9] this phenomenon could not be discriminated, although its existence has been mentioned in a number of studies [5, 6]. In the summer in the area of the Andaman Sea it is easy to trace the transport of waters primarily of a northerly direction, with a width of 350-450 km and an extent of more than 1000 km with velocities of about 10 cm/sec, which is impaired in winter. The mentioned peculiarity of circulation was found for the first time in computations of geostrophic currents in this basin.

South of the equator (Fig. 1), between 8 and 10°S, a branch of the STC is clearly manifested; it extends from ESE to WNW. During summer it intensifies to 40 cm/sec and adjoins the shores of Java. In winter the axis of the STC is traced somewhat to the south and along the shores of Java there is water transport in an easterly direction. Such a transformation of the surface circulation system is evidently attributable to the change in the wind regime of this region. The results agree well with the data published by V. G. Kort [5].

To the north and south of the axis of the STC it is easy to discriminate quasistationary eddy formations, which confirms modern concepts concerning the dynamics of waters in this region [5, 12]. The sign of vorticity of these circulations makes it possible to judge the vertical movements of waters in

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these regions: to the north of the main flow of the STC there is a predominance of cyclonic (southern hemisphere) eddies (upwelling of waters in the south equatorial divergence), and to the south -- anticyclonic eddies (subsidence of waters in the convergence region).

In summarizing these investigations we note the following:

1. In diagnostic computations for the first time it was possible to obtain such significant elements of the circulation of waters as the unified flow of the monsoonal current, summer intensification of the equatorial countercurrent for the distance from 80°E to the shores of Sumatra and seasonal movement of the STC relative to the shores of Java, which were mentioned earlier in the literature. Quantitative evaluations of the spatial-temporal (seasonal) variability of the enumerated flows were given.

2. The noted agreement of the results of computations and data from the preceding investigations indicates the effectiveness of the procedures used in the processing of in situ observations and therefore they can be recommended for broader introduction in the practice of oceanographic research.

3. The interrelationship between summer intensification of anticyclonic circulation of waters in the Bay of Bengal and intensification of the monsoonal current was clarified.

4. A flow of northerly direction with a width of 350-450 km and an extent of more than 1000 km, not previously described in the literature, was found to exist in summer in the Andaman Sea.

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DETERMINING STATISTICAL CHARACTERISTICS OF PASSIVE IMPURITY FIELD IN SEA WATER USING CONSERVATIVE MARKER

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 (manuscript received 4 Jun 81) pp 71-74

[Article by S. V. Semovskiy, State Oceanographic Institute]

[Abstract] The author has ascertained the correlation function of the field of a dissolved passive impurity in the open part of the sea on the basis of the correlation function for the salinity field. In addition, it was possible to ascertain the mean field of an impurity in the mouth regions of rivers on the basis of the mean salinity field. Finally, a method was defined for determining the self-purifying capacity of the sea medium by means of study of the field of a conservative marker. In the first part of the paper it is shown that with a known correlation function of the salinity field and a known self-purifying capacity of the medium it is possible to ascertain the correlation function of the field of a passive dissolved impurity; the formula derived for this purpose is simple if a stationarity of field fluctuations is assumed, otherwise the analysis is more difficult. The discussion of the river mouth zone in the sea focuses on the behavior of a passive dissolved impurity transported by river waters, the assumption being made that the river is the sole source of entry of the impurity into the considered part of the sea. An expression is derived for explaining the behavior of the impurity on the assumption that there is a common mechanism for the propagation of fresh water and the impurity. If the mean salinity field in the dilution zone has been described it is possible to describe the mean field of the transported impurity by knowing only the background concentrations and the nonconservativity index. The proposed methods are relatively simple because observations of the salinity field are not difficult and salinity is a conservative marker of hydrochemical fields. Having data on the statistical structure of the fields of salinity and contaminating substances it is possible to evaluate the self-purifying capacity of the sea medium. References: 5 Russian.

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INVESTIGATION OF SURFACE FILM TEMPERATURE FROM RESULTS OF SEA OBSERVATIONS

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 (manuscript received 27 May 81) pp 75-79

[Article by V. V. Shigayev, S. N. Druzhinin and V. L. Lebedev, candidate of geographical sciences, Moscow State University]

[Text]

Abstract: The authors analyze the results of temperature sounding of the quite thin water-air interface obtained by the Multidiscipline Eastern Expedition of the Geography Faculty, Moscow State University, in the Sea of Japan in July-August 1980. The existence of molecular thermal conductivity films in the water (δ_w = 0.001-0.003 m) and in the air (δ_a = 0.0005 m) was noted with a mean ratio: δ_a/δ_w = 1/2 - 1/3. For the first time for marine conditions it was possible to obtain empirical dependences of the deviations of water radiation temperature, introduced by the film (ΔT), from the temperature of the subsurface water in dependence on the total heat flow (Q_Σ) and wind velocity at a height of 10 m (U_{10}). With U_{10} about 2 m/sec $\Delta T = 4.56 \cdot 10^{-3} Q_\Sigma$, with U_{10} = 3-4.5 m/sec -- $\Delta T = 2.6 \cdot 10^{-3} Q_\Sigma$ with correlation coefficients 0.93 and 0.90. The applicability of the correlation coefficient value A = 0.25 between the Nusselt and Rayleigh numbers is demonstrated; this makes it possible to determine ΔT during calm weather and periods of little wind.

The basis for the design of the employed thermosonde was the work of Ye. G. Andreyev and G. G. Khundzhua [2]. Registry was in the coastal zone of the sea from a small float at a distance of 20-30 m from the ship; this small float was connected to the ship's side by a cable which was supported by other small floats. The relative temperature was registered at the same time by an automatic recorder at a scale of 1:1 and was photographed from the screen of an oscillograph. The sensor used was a copper-droplet thermocouple with a wire

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diameter of 30 μm. The sounding rate was about 0.11 m/sec. The error in measuring temperature at a stipulated depth was about 0.05°C and was determined using the formula [9]

$$\delta T = \theta v \frac{\partial T}{\partial z}, \tag{1}$$

where θ is the thermal inertia time of the sensing junction of the thermocouple, determined experimentally ($2.0 \cdot 10^{-3}$ sec), v is the rate of submergence of the temperature sensor, $\partial T / \partial z$ is the measured temperature gradient.

The depth of submergence of the thermosonde in the sea is -0.10 m. There was registry of about 600 continuous temperature profiles in the water and air from the float in series with sounding intervals of 1-2 minutes.

Parallely with operation of the thermosonde, specialists on the ship at intervals of 15-30 minutes carried out observations of air humidity, wind and water temperature at the horizon 0.4 m.

In order to systematize the temperature profiles the observation period was broken down into several groups. The principal criterion in discriminating the groups was wind conditions. Other characteristics (e_0-e_{10} -- the difference in saturation elasticity directly over the water and water vapor saturation elasticity at a height of 10 m; $T_w - T_a$ -- the temperature difference between water at a depth of 0.4 m and air temperature at a height of 10 m) to a greater or lesser degree changed as a result of changes in wind speed.

The temperature profiles were registered at two scales: on the automatic recorder at a scale of 1:1 and with 10^x enlargement on the photographed oscillograph screen.

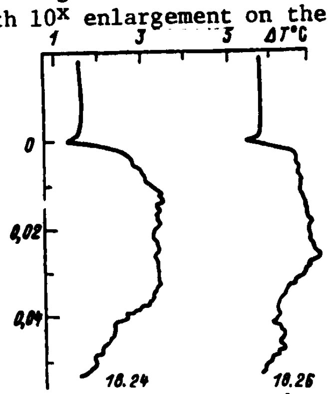

Fig. 1. Vertical profiles of temperature obtained under forced convection conditions by sounding upper water layer at a scale 1:1 on 20 August 1980.

Figure 1 shows a characteristic example of a small-scale temperature profile record. On virtually all the profiles near the surface as a rule it is possible to discriminate viscous air and water sublayers with a thickness of about 0.001-0.003 m, detectable on the photographs from the oscillograph screen from sectors with a linear distribution of temperature, corresponding to a constant thermal conductivity coefficient. The approximate relationship of the thicknesses of these layers is δ_a / δ_w = 1/2 - 1/3. The latter agrees with the theoretical predictions of Kraus [7].

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In most cases there was registry of a cold film ΔT = 1-3°C (about 70% of the cases). In many cases the film had a poorly expressed character; in 10% of the cases there was a warm film with ΔT up to 3°C.

The thickness of the surface temperature film changed constantly with time (from 0 to 0.006 m); there was also a change in the temperature drop in it. Thus, a film is a pulsating natural formation.

An attempt was made to find the value of the temperature correction ΔT introduced by the film to the temperature of the sea surface at different wind velocity and heat balance values for the surface water layer of about 0.003 m. Two computation schemes were used. In the first the balance was computed using the standard method using the formulas for the heat flow due to evaporation and condensation Q_E and contact heat exchange Q_H [5]:

$$Q_E = 5{,}87 \cdot 10^{-5} (0{,}26 + 0{,}077\, U_{10})(e_0 - e_{10}), \tag{2}$$

$$Q_H = 3{,}87 \cdot 10^{-5} (0{,}26 + 0{,}077\, U_{10})(T_w - T_a). \tag{3}$$

Effective radiation Q_{eff} was computed using oceanographic tables with the use of the observed cloud cover and humidity values. The purpose of processing of the results was an examination of the convergence of the sign of the sum $Q_E + Q_H + Q_{eff}$ and the "sign" of the film. The result indicated a partial convergence of the signs. A hypothesis can be formulated along these lines.

The excessively strong simplification of the computation scheme did not make it possible to achieve sufficiently precise results. The computations were complicated also by the fact that 20% of the measurements were made in a fog and more than 30% under calm conditions. The accuracy of formulas (2) and (3) under these conditions is considerably reduced. There is no correction for a fog for the computation formulas. Many researchers have met with such difficulties [6].

The second computation scheme involved computing the total heat flow in the temperature gradient in the part of the temperature profile which is close to linear, directly bounding with the water-air surface. The sector of molecular thermal conductivity is sometimes identified with a linear temperature distribution, but this is correct only under stationary conditions. Assuming that the boundary of the phases does not have a thickness and there is no heat accumulation in it, we can write the expression

$$\lambda \left.\frac{\partial T}{\partial z}\right|_{z=0} = Q_E + Q_H + Q_{eff} = Q_\Sigma , \tag{4}$$

where λ is the thermal conductivity coefficient.

The temperature gradient necessary for the computations is determined from the oscillograph photographs. With respect to the flow of solar heat (Q_s), for the heat balance of the film the only factor of importance is its absorption within the limits of the film (0.001-0.003 m). This absorption was not taken into account in our work (as in many other investigations, such as [9]) and this did not make it possible to determine the conditions for formation of the warm

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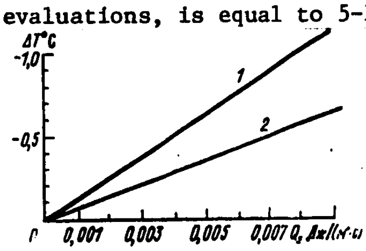
film. Data on the absorption of radiation in the layer 0.001 m are given in [8]. The values of the Q_Σ parameter, regardless of the method for its determination, make it possible to check and refine the formulas relating the total temperature drop in the film (including the linear and nonlinear parts of the profile) with the wind and heat balance. We note the circumstance that when determining Q_Σ from the temperature gradient use was not made of the total temperature drop, but the tangent of the profile slope in its "linear" part in contact with the sea surface.

The Saunders formula [12] has come into wide use; it is based on the theory of dimensionalities

$$\Delta T = \frac{kQ_\Sigma \nu}{\lambda (\tau/\rho_w)^{1/2}}, \tag{5}$$

where ν is the molecular kinematic viscosity of water, τ is wind shearing stress, ρ_w is water density, λ is the coefficient of molecular thermal conductivity, k is a dimensionless coefficient which, according to the Saunders theoretical evaluations, is equal to 5-10.



Q, J/(m·sec)

Fig. 2. Dependence $\Delta T = f(Q_\Sigma)$ in forced convection regime with different wind speeds at height of 10 m. 1) U_{10} = 2 m/sec; 2) U_{10} = 3.0-4.5 m/sec.

Hasse [10] simplifies formula (5), combining little-changing factors into the dimensional coefficient C and replacing friction velocity $(\tau/\rho_w)^{1/2}$ by velocity at the stipulated height U_{10}:

$$\Delta T = C Q_\Sigma / U_{10} \tag{6}$$

It is known from measurements in wind tunnels and channels that C changes little from the depth from which the temperature deviation introduced by the film ΔT is reckoned (C = 9.4 for 0.25 m and 9.9 for 1 m when measuring Q in cal/(cm^2·min), U_{10} in m/sec).

Hasse discovered that equation (6) corresponds to observations in the sea in the range of wind velocities 1.45-11.35 m/sec (ΔT was read from the horizon 0.35 m). A better approximation was attained with C = 9.2.

The processing of our sea observations of 1980 indicated that for a cold film in the case of forced convection ($U_{10} > 0.5$ m/sec) and in the absence of fog the best results are given by the formula

$$\Delta T = 0{,}23 + 6{,}16 \cdot 10^{-3} Q_\Sigma / U_{10} \quad (Q_\Sigma \text{ in W/m}^2). \tag{7}$$

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In the case of a fog (about 120 observations) the values of the constants in the formula change:

$$\Delta T = 0{,}39 + 4{,}05 \cdot 10^{-3} Q_{\Sigma}/U_{10}, \quad (8)$$

the correlation coefficients for formulas (7) and (8) are equal to 0.59 and 0.79.

The temperature correction formula for a cold film, generalized for the entire mass of data (about 460 observations in 1980) for wind velocities 0.5-4.1 m/sec, has the following form:

$$\Delta T = 0{,}24 + 4{,}58 \cdot 10^{-3} Q_{\Sigma}/U_{10}. \quad (9)$$

In the derivation of formulas (7), (8) and (9) the temperature deviation in the film was computed as the temperature difference at the surface and at the depth where the total temperature drop of the film was attained, which excluded the distortions which can be introduced into the computations with temperature changes in the diurnal thermocline [13].

For small wind velocity ranges from the mass of 400 profiles we derived formulas for a cold film with high correlation coefficients (0.93 and 0.90) for a wind with a velocity 3-4.5 m/sec (Fig. 2)

$$\Delta T = 2{,}6 \cdot 10^{-3} Q_{\Sigma}. \quad (10)$$

For a wind with a velocity of about 2 m/sec

$$\Delta T = 4{,}56 \cdot 10^{-3} Q_{\Sigma}. \quad (11)$$

For clarifying the dependence of ΔT on Q_{Σ} in the case of free convection ($U_{10} < 0.5$ m/sec) in the case of a cold film we take the relationship between the Nusselt and Rayleigh numbers [4]

$$\mathrm{Nu} = A\,\mathrm{Ra}^h, \quad (12)$$

where

$$\mathrm{Nu} = \frac{Q_{\Sigma}}{\lambda \Delta T/\delta}, \quad \mathrm{Ra} = g\alpha \Delta T \delta^3/\varkappa\nu,$$

$\varkappa$, ν are the coefficients of molecular thermal diffusivity and the kinematic viscosity of water, α is the coefficient of volumetric thermal expansion, δ is film thickness.

On the basis of (12) the temperature drop in the film is

$$\Delta T = A^{-3/4} (g\alpha c_p \rho_w \lambda^3/\nu)^{-1/4} Q_{\Sigma}^{3/4}, \quad (13)$$

where c_p is the specific heat capacity of water at constant pressure.

It follows from formula (12) and the theory of dimensionalities that h must be equal to 1/3. For determining the A coefficient we carried out a number of laboratory experiments (but not one sea measurement). According to laboratory investigations, the A value is close to 0.22-0.25 [3, 4].

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We constructed a graph of the dependence of ΔT on Q_{Σ} for free convection conditions. This demonstrated that formula (13) approximates well the results of the sea measurements analyzed with A = 0.25.

An attempt to construct the dependence of Δ T and δ only on wind velocity, bypassing data on the heat balance, did not give stable results. It is only possible to speak of a tendency in the direction of a decrease in Δ T and δ with an increase in wind velocity for the cold film and an opposite tendency for a warm film.

As noted above, for an analysis of the conditions of formation of a warm film it is necessary to have data on the absorption of radiation in the upper layer of water 0.001 m. Our attempts to relate the appearance of a warm film only to the Bowen number (Bo = Q_H/Q_E) did not give a stable correlation.

Thus, the interesting and poorly studied phenomenon of a warm film undoubtedly will require a more complete allowance for the heat balance components.

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APPROVED FOR RELEASE: 2007/02/09: CIA-RDP82-00850R000500080060-2

UDC 556.535.3+556.166

COMPUTATIONS OF MAXIMUM WATER DISCHARGES IN MULTIFLOOD REGIME

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 (manuscript received 22 Jul 81) pp 80-90

[Article by B. Ya. Kagan, candidate of technical sciences, Leningrad Division, "Gidroproyekt" Institute]

[Abstract] Methods for computing the maximum discharges of rain-induced high waters in rivers on the basis of a series of the maximum high-water discharges in a year exclude from consideration considerable information on high waters not included in this series and therefore should be improved. Allowance for all high waters of practical significance, as shown here, can increase the reliability in computing the probable values of the high-water discharge which is the maximum for a year. The computation procedures outlined in this article are based on allowance for all high waters "of practical significance" and the application of objective methods for extrapolation of the integral probability distribution curves. This makes possible a more reliable determination of the computed maximum water discharges than when using a series of the maximum high waters during the year or when using the mean number of excesses of stipulated water discharges. As defined here, a high water "of practical significance" is one whose maximum discharge was equal to or exceeded the smallest of the high-water discharges which were the maximum during the year over a long-term period of observations. Such an approach gives basis for assuming that each high water "of practical significance" could be the maximum during one year or another. The method makes it possible to construct guaranteed probability curves of peak water discharges. Application of the proposed method will be especially valuable for short series of observations on rivers with a large number of high waters. Figures 2; tables 5; references: 11 Russian.

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UDC 551.311.21

APPLICATION OF NUMERICAL METHOD IN COMPUTING UNSTEADY MOTION OF COHESIVE MUDFLOW ALONG WATERCOURSE

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 (manuscript received 2 Jun 81) pp 91-97

[Article by V. I. Tevzadze, candidate of technical sciences, D. G. Gordeziani, candidate of physical and mathematical sciences, and I. K. Keshelava, Georgian Scientific Research Institute of Hydroengineering and Melioration; Institute of Applied Mathematics, Tbilisi State University]

[Abstract] The authors propose a numerical method for computing the unsteady motion of cohesive (highly concentrated) mudflows, making use of appropriately adapted St. Venant equations. As indicated in this paper, the preparation of the computer program for this purpose requires the setting of clear initial and boundary conditions. The unsteady motion of a cohesive mudflow along a watercourse can be divided roughly into three main phases: "beginning of motion," "motion along the channel" and "stoppage" when gravitational and other forces put an end to the motion. It is shown that each of these phases has its peculiarities with respect to the mathematical formulation of the problem, preparation of the program and its subsequent realization. The most difficult task, the assignment of initial and boundary conditions, must be done in such a way that thereafter in all sectors and within these sectors it will be possible to determine the indices of the dynamics of flow, depth and velocity of motion. The limitations imposed in this problem are very significant and to some extent they seem to make the modeled phenomenon unrealistic, but no other solution seems possible. The method proposed here, on the other hand, does seem to afford a possibility for predicting the principal dynamic and geometrical indices of the flow in both time and space, which is very important for the rational placement of protective antimudflow structures in the channel and on the floodplain. The method essentially involves solving a difference analogue of a system of quasilinear equations in partial derivatives of the hyperbolic type. The Courant condition is satisfied during the computations for different relationships of space and time grid intervals. This also involves application of a special procedure based on truncation of the flow depth value as the so-called critical value is approached. The authors give a table of depths and velocities of a cohesive mudflow for corresponding times and distances from the initial point for specific values of the stipulated parameters. Figures 2, tables 1; references: 19 Russian.

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UDC 631.436:551.521.31(575)

ENERGY POTENTIAL OF LOWLAND PART OF CENTRAL ASIA AND ITS USE BY PHYTOCOENOSES

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 (manuscript received 31 Aug 81) pp 98-102

[Article by I. G. Gringof, candidate of biological sciences, and N. S. Konovalova, All-Union Scientific Research Institute of Agricultural Meteorology; Central Asian Regional Scientific Research Institute]

[Abstract] There is a recognized need for a detailed assessment of the receipts of photosynthetically active radiation (PAR) in the territory of Central Asia. The authors therefore undertook a detailed description of the energy resources of the desert territory of the country and analyzed the effectiveness of use of solar energy by different types of pastures in the lowland part of the republics of Central Asia, the area of the Karakum and Kyzylkum deserts. The receipts of PAR were computed by the commonly employed Yu. K. Ross method. Different formulas are used for clear and cloudy conditions. In this region the distribution of total radiation and PAR conforms to the laws of latitudinal zonality. The sums of PAR were computed for each month, year and for the active growing season of desert-pasture vegetation for all points where standard meteorological observations are made. During the growing season the PAR sums vary from 55 Cal/cm^2 in the north to 85 Cal/cm^2 in the south (Fig. 1 is a map of the distribution of PAR). This map showing PAR receipts during the growing season reflects not only the patterns of distribution of solar radiation, but also the distribution of air temperature. However, in years differing in meteorological conditions the PAR sums deviate from the mean long-term values. An important index characterizing plant productivity with respect to their photosynthetic activity is the solar energy utilization factor; Table 1 gives the sums of PAR from the date of spring transition of mean daily air temperature through 0°C to the date of the maximum height of the grass stand; Table 2 gives the solar radiation utilization factors for different types of pastures. In years with optimum moistening the utilization factor increases to 0.3, whereas in years of drought it decreases to 0.06. Plants of these arid and semiarid regions are characterized by extremely low solar energy utilization factors. Figures 2, tables 2; references 19: 17 Russian, 2 Western.

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APPROVED FOR RELEASE: 2007/02/09: CIA-RDP82-00850R000500080060-2

UDC 551.509.615:551.509.616

INFLUENCE OF MIXING ON FORMING OF ICE NUCLEI WITH INTRODUCTION OF SOLID CARBON DIOXIDE INTO CLOUD

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 (manuscript received 4 May 81) pp 103-106

[Article by P. M. Mushenko, candidate of physical and mathematical sciences, Leningrad Hydrometeorological Institute]

[Abstract] The problem of the conditions and mechanism of generation of ice particles near CO_2 particles still remains unclear. In particular, this is true of the evaluation of the degree of water vapor supersaturation arising as a result of the cooling effect of solid CO_2. In this paper it is demonstrated that the widely accepted belief that there is an identity of the conditions for the generation of ice crystals near the surface of an evaporating particle of solid CO_2 and the surface of a nonevaporating body of the same temperature is erroneous. This is true because other researchers have neglected the diffusion of CO_2 gas forming as a result of the evaporation of solid CO_2, making the assumption that in the entire zone of the cooling effect the vapor elasticity is equal to the elasticity of vapor in the cloud. In actuality, vapor elasticity in the zone of the effect is a function of temperature, whose field is formed as a result of the mixing of dry and cold CO_2 gas and moist relatively warm air. The discussion reveals clearly that the probability of the formation of ice particles near the surface of solid CO_2 is greater than near water particles. Accordingly, the neglecting of the mixing effect can lead to considerable errors in computations of the number of ice heterophase nuclei forming near the cooling surface of solid CO_2 as a reagent in the artificial modification of supercooled clouds and fogs and therefore there will be errors in evaluating the total probability of formation of ice particles in the entire zone of artificial modification. Tables 1; references 7: 6 Russian, 1 Western.

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ARTIFICIAL CRYSTALLIZATION OF SUPERCOOLED AQUEOUS AEROSOLS

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 (manuscript received 19 May 81) pp 106-108

[Article by L. G. Kachurin, professor, N. O. Grigorov and V. F. Psalomshchikov, candidates of physical and mathematical sciences, and A. I. Plugin, Leningrad Hydrometeorological Institute]

[Abstract] The authors propose a fundamentally new means for intensifying crystallization in clouds related to the change in conditions for the introduction of reagents. It is clear that by increasing supersaturation in some local zone of injection of a reagent into a cloud it is possible to achieve a considerable decrease in the critical size of heterophase (2- and 3-dimensional) nuclei and therefore bring about an increase in the number of active reagent particles. The method involves creation of a local supersaturation by use of a jet of supersaturated steam. The authors first examine the crystallizing effect of the supersaturated vapor itself. During 1975-1979 new laboratory experiments were carried out in a fog chamber under a wide range of conditions. The chamber temperature was varied in the range from -5 to -25°C. A high-velocity jet of supersaturated vapor was created in a specially developed steam generator. The jet had a supersonic velocity. The experiments revealed that the activity of the vapor as a crystallizing agent increases sharply due to a decrease in the cross section of the jet or an increase in the escape velocity of the jet. The temperature dependence of the crystallizing activity of the water vapor was similar to that observed for well-known reagents such as silver iodide. However, the absolute value of the ice-forming activity of the vapor is still considerably lower than the activity of the presently employed crystallizing reagents. Nevertheless, there are definite possibilities for increasing the activity of the vapor by an increase in the velocity of the jet and a simultaneous increase in the intensity of its interaction with the medium. A combined method can be employed: use of crystallizing reagents introduced into the chamber together with a jet of supersaturated water vapor. Experiments were carried out with two such reagents. This enhanced the crystallizing effect. Figures 3; references 5: 4 Russian, 1 Western.

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APPROVED FOR RELEASE: 2007/02/09: CIA-RDP82-00850R000500080060-2

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ELECTRIC FIELD POTENTIAL GRADIENT UNDER CONDITIONS OF ATMOSPHERIC INDUSTRIAL POLLUTION

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 (manuscript received 27 Apr 81) pp 108-111

[Article by A. A. Krechetov, candidate of geographical sciences, A. Kh. Filippov, candidate of physical and mathematical sciences, and V. K. Tatarnikov, Irkutsk State University; Baykal Hydrometeorological Observatory]

[Abstract] Aerosols of different origin can exert an important influence on the electrical properties of the atmosphere. It has been demonstrated that the gradient of electric field potential and conductivity are dependent on atmospheric contamination by industrial aerosols. Electrically charged aerosols are discharged from factory stacks and create space charges. The authors made investigations of this phenomenon in July 1979 and March-April 1980, determining the atmospheric electric field potential gradient in the neighborhood of the Baykal Cellulose-Paper Combine. The collector method was employed in measuring the potential gradient. Synchronous observations were made at three points: Baykal'sk, Solzan and Murino, at distances of 5, 20 and 200 km from the combine (1979) and at two others-- Baykal Hydrometeorological Observatory and on the ice of Lake Baykal (1980). Other supplementary measurements were also made. It was found that industrial effluent exerts an important effect both on the mean daily potential gradient values and on its diurnal variations (these are discussed in detail). The general patterns of this influence have a relatively stable character. Negative potential gradients are regularly observed in the region below the plume. This can be used in indicating plume propagation. The effluent from the stacks of the cellulose-paper plant cause an increase in the positive potential gradient by a factor of 2 in comparison with the clear sky. The spatial correlation of the mean hourly potential gradient values in the Baykal'sk area is complex. In some cases the influence of industrial effluent on the electric field can be detected at a distance of about 20 km. Figures 2, tables 3; references 5: 4 Russian, 1 Western.

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APPROVED FOR RELEASE: 2007/02/09: CIA-RDP82-00850R000500080060-2

UDC 551.508.9:519.242

ANALYSIS OF LONG TWO-DIMENSIONAL SERIES OF LIGHT SIGNAL MEASUREMENTS IN ATMOSPHERIC SURFACE LAYER

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 (manuscript received 16 Jul 81) pp 112-119

[Article by V. P. Pashchenko, doctor of physical and mathematical sciences, Scientific Research Institute of Instrument Making]

[Abstract] Domodedovo, Vnukovo, Sheremet'yevo and Borispol' airports are supplied with the M-105 triangulation apparatus which makes it possible to determine the lower cloud boundary. A searchlight, situated 100 m from a receiver, moves in angle of elevation in such a way that a reflected signal is received and registered whenever the level of the reflected signal exceeds the receiver triggering threshold. As a result, in time-height coordinates, the tape shows a pattern of vertical lines which characterize optical density. When multiday continuous measurements are made each 30 sec the system of vertical lines forms a two-dimensional distribution which can be matched with a specific meteorological situation. The information which can be deduced is the subject of this detailed article. Snow, for example, when falling from clouds above 1000 m, is registered as a specific pattern of vertical continuous or dashed lines. Light snow showers are characterized by vertical bands filled with occasional dashed lines; heavy snow is characterized by vertical bands with a dense pattern of solid lines and few dashed lines. Fogs of different types also have their typical patterns. The reflections from different genera and species of clouds can be interpreted with considerable accuracy and a key has been worked out which is quite sophisticated and may represent a genuine advance in the registry of this highly variable phenomenon. Figures 5; Tables 5; references: 2 Russian.

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SEVENTIETH BIRTHDAY OF IGOR' VLADIMIROVICH POPOV

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 pp 120-121

[Article by personnel at the State Hydrological Institute]

[Abstract] Professor Igor' Vladimirovich Popov, doctor of geographical sciences, an outstanding Soviet specialist in the investigation of river channels and one of the creators of the hydrological-morphological theory of the channel process, marked his 70th birthday on 9 April. His father was a distinguished agricultural meteorologist, the director of the Main Geophysical Observatory and head of the hydrophysics division at the State Hydrological Institute. With such an illustrious heritage, I. V. Popov studied at Leningrad State University, from which he graduated in 1936, and was then sent to the State Hydrological Institute, where he works even at the present time. During the war he served as both a combat soldier and in military meteorological assignments. He defended his candidate's dissertation in 1948, with his thesis being devoted to methods for carrying out hydrographic work and the use of aerial photographic surveying in hydrology. After 1956 he directed his attention to investigation of river channel deformations. During this period he worked in close collaboration with N. Ye. Kondrat'yev. Together they outlined the fundamentals of the hydrological-morphological theory of channel processes, clarified the typical patterns of morphological formations and developed methods for computing and predicting channel and floodplain deformations. I. V. Popov played an important role in the extensive use of aerial photographs in studying reformations of river channels. Popov is the author of more than 100 scientific articles, study aids and instructions. The results of his own many years of research were generalized in his doctoral dissertation, defended in 1966. The most important studies of I. V. Popov are well known abroad. His work as a teacher has also been outstanding. Figures 1.

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ACTIVITIES AT USSR STATE COMMITTEE ON HYDPOMETEOROLOGY AND ENVIRONMENTAL MONITORING

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 pp 121-122

[Article by V. N. Zakharov]

[Abstract] The Board of the State Committee on Hydrometeorology and Environmental Monitoring on 11 February 1982 examined the problems involved in increasing the efficiency of work by scientific research institutes and directing the efforts of these organizations to the most important research fields. Every effort is being made to increase the results of research, to enhance the quality of such investigations, ensure the speediest possible practical introduction of the results into different branches of the national economy and to improve the organization of scientific research. Measures have been adopted to ensure the speediest possible completion of planned research both during the year and during the five-year plan. One such measure has been the requirement that work results be evaluated by a panel which includes representatives from outside the institute; for example, in the review of work done at one insttute the panel reviewers included 12 specialists from 8 organizations of other ministries and departments. Since 1981 many steps have been taken to strengthen central monitoring of the work accomplished by subordinate scientific research institutes and experimental design bureaus. This has been coupled by efforts to improve structure of field organizations and to eliminate inefficiently operating subdivisions; for example, the West Siberian Regional Scientific Research Institute has been separated from the West Siberian Administration of Hydrometeorology and Environmental Monitoring and this should result in an intensification of work on developing weather forecasting methods. Much attention has been devoted to evaluations of the economic efficiency of scientific research and experimental design work. In December 1981 the Committee established a Central Methodological Commission on Efficiency for examining methods for evaluating economic efficiency and for coordinating work in this field. The Main Geophysical Observatory will oversee work in this area. A symposium on this subject was held at the observatory during the period 15-16 April 1981. During 1981 there was multisided checking of the activity of seven scientific research institutes. Such centralized supervision and review is achieving increased productivity and quality of work. Emphasis must be on achievement of results which will have application in the national economy.

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CONFERENCES, MEETINGS AND SEMINARS

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 pp 122-127

[Article by I. A. Yankovskiy, D. V. Kozinets, A. G. Prosvirkina and S. G. Malakhov]

[Abstract] A Soviet-American symposium on prediction of the behavior of pesticides in the environment was held at Yerevan during the period 21-28 October 1981. Eleven American and 49 Soviet scientists in attendence heard 17 Soviet and 10 American reports. The final resolution defined the principal direction in future research to be the development and further improvement of mathematical models of migration and transformation of pesticides in the environment. The parameters of these models should be functions of the most significant environmental properties. In addition, there is a need for developing empirical (such as balance) prognostic models. In the future there will be not only development and joint testing of mathematical models, but also joint study of the processes of microbiological decomposition of pesticides, evaporation processes, photochemical degradation, etc. in soils, and a number of other important problems. Summaries of the symposium reports have been published in a separate brochure. The full texts of the reports will be published in Russian and English in 1983.

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An organizational meeting of the Scientific Council on Agrometeorological Problems was held at Obninsk during the period 5-6 October at the All-Union Scientific Research Institute of Agricultural Meteorology. The director of that institute, I. G. Gringof, presented a review report on achievements in agrometeorology during the 10th Five-Year Plan and goals for the 11th Five-Year Plan. Among the achievements of the last five years he emphasized the following: progress in developing the agrometeorological aspects of the quantitative theory of the formation of the yield of agricultural crops; development and improvement of statistical methods for agrometeorological predictions of the yield of agricultural crops; broader use of new types of data obtained by remote methods; much progress in the automation of the collection and processing of observational data; development of methods for evaluating and predicting the influence of agrometeorological conditions on the development of agricultural pests; work on evaluating agroclimatic conditions for cultivation work and validation of the distribution of agricultural crops in the zone of the Baykal-Amur Railroad and in Transcaucasia. Among the major problems to be dealt with during the next five-year plan and up to 1990 are the following: creation

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of agrometeorological monitoring. This should constitute a system of observations and monitoring of agrometeorological and microclimatic conditions and the state of fields of agricultural crops and natural pastures. The objective of monitoring would not be a passive evaluation of the state of the environment and vegetation, but routine processing of the arriving information and the modeling of processes with the dissemination of predictions and recommendations as a basis for adopting optimum and routine economic decisions. Methods for predicting yields of agricultural crops must be improved. There is a need for upgrading of agroengineering techniques, agroclimatic regionalization must be improved and further improvements in the automation of the system for the collection and processing of agrometeorological data are required.

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An all-union seminar on the monitoring and preservation of atmospheric air was held during the period 20-24 October 1981 in Moscow; it was attended by the heads of centers for environmental monitoring and other scientific specialists; similar seminars were held during the year in other regions. At these seminars considerable attention was devoted to improvements in the network for monitoring atmospheric contamination, the organization of control posts for monitoring atmospheric contamination and optimizing observations. A wide variety of pertinent subject matter was discussed, such as: monitoring the propagation of the most common harmful impurities which must be regularly observed; analysis of errors in sampling and analyzing air samples; prediction of the contamination of atmospheric air in cities; setting of norms for the maximum admissible concentrations of pollutants; analysis of dust content in industrial effluent; analytical methods employed in monitoring the environment; issuance of reference manuals on a wide range of topics; theoretical and methodological problems; introduction of improved monitoring instruments.

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NOTES FROM ABROAD

Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 5, May 82 pp 127-128

[Article by B. I. Silkin]

[Abstract] As reported in NEW SCIENTIST, Vol 92, No 1275, 1981, twenty years ago when it was determined that organochloride pesticides (DDT, aldrin, dieldrin, and others) cause an increase in mortality and decrease in fertility in animals the authorities in Great Britain adopted measures for restricting the use of these substances. Unfortunately, there was no provision for enforcement. It is now clear that the desired results have not been forthcoming. The statistics reveal that the mean annual quantity of organochloride pesticides used in Great Britain between 1975 and 1979 was 5% greater than between 1971 and 1974. There evidently has been no appreciable decline, for example, in the content of DDE in the environment. Since DDT is three times cheaper than less stable and less harmful pesticides it is improbable that farmers will voluntarily desist from its use. Accordingly, British environmentalists are insisting on the adoption of mandatory measures against the use of organochlorides.

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It is reported in SCIENCE NEWS, Vol 120, No 8, 1981, that during the entire summer of 1981 specialists working near Miles City, Montana, carried out an experiment for studying convective precipitation. A total of 125 scientific workers representing 29 research institutes participated. Over 10 instrument-equipped aircraft were used in the work; ordinary and Doppler radars were employed, making it possible to trace the movement of individual moisture particles in a thunderstorm cell where hail is generated. Data from aircraft observations were continuously transmitted to ground stations where electronic computers immediately made these data available to investigators. A network of automatic solar-powered meteorological stations was in operation over an extensive area and disseminated data hourly, sometimes via satellite. The processing of the great volume of collected data will require several years, although much preliminary material is already available.

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